Chapter 6

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R645-301-610 Introduction

This chapter describes the general geological conditions of the permit and adjacent areas and identifies whether the conditions are acceptable for recovery of the coal by underground methods.

R645-301-611 General Requirements

Descriptions of the geology within and adjacent to the permit area is given under R645-301-620 through 627.

R645-301-612 Cross-Sections Maps and Plans

All cross-sections, maps, and plans as required by R645-301-622 have been prepared and certified as described under R645-301-512.100

R645-301-620 Environmental Description

Regional and Structural Geology

The mining site lies at the base of an erosional escarpment that forms the eastern face of the Wasatch Plateau, a subdivision of the Colorado Plateau physiographic province. East of the Wasatch Plateau is Castle Valley, a relatively flat area over 80 mi long and 10 mi wide trending northeast-southwest. East of Castle Valley lies the San Rafael Swell, a great upfold marked by rings of hogback hills and intervening valleys.

The Wasatch Plateau is a high, broad, flat area dissected by numerous streams. The high plateaus of Utah, which include the Wasatch Plateau, are thought to be a transition zone containing geologic structures common to both the Colorado Plateau Province and the Basin and Range Province to the west.

The C.W. mining site is located near the east central edge of what is known as the Wasatch Plateau coalfield. The plateau edge is a steep cliff with a maximum relief of about 1,000 ft, coal outcrops appear in the canyon walls and along the cliffs. Rock types at the site are late Cretaceous in age and are generally composed of gray sandstone of fine to medium grain, interbedded with subordinate gray and dark gray carbonaceous shale and coal present with continental and/or transitional sediments. Marine sediments occur below the sequence and are exposed to the east of the escarpment in the Castle Valley.

Table 6-1 gives the generalized stratigraphic sequence and unit description of the Wasatch Plateau. The oldest rocks are of the early upper Cretaceous age. The major commercial coal seams occur in the Black hawk formation and are of Campanian age.

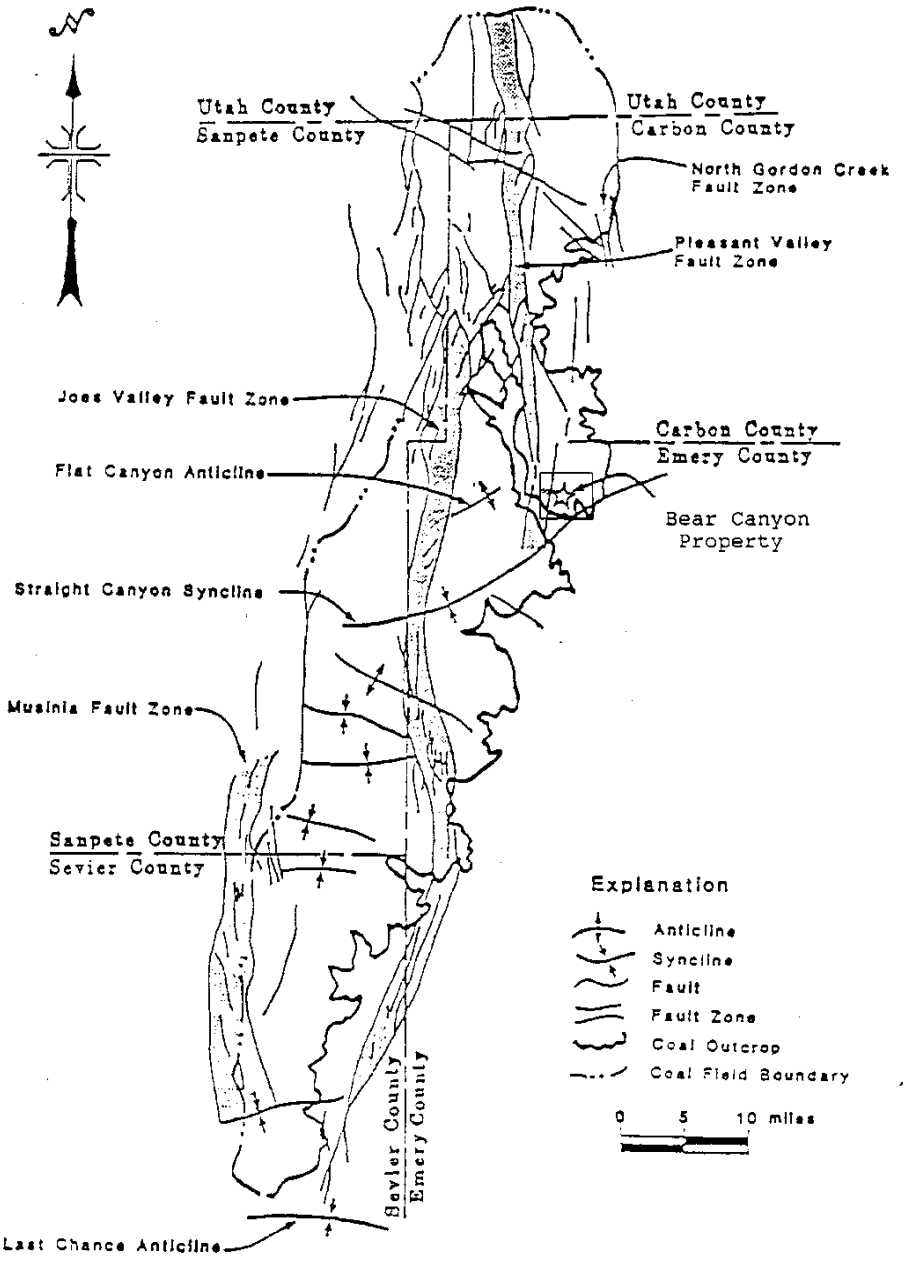
Structurally, strata in the Eastern Wasatch Plateau generally dip southerly (sometimes slightly southeast of southwest) at low angles of 1 to 3 deg. Locally, near faults, the dip increases to about 20 deg. Three major north-south trending fault zones have been defined in the Wasatch Plateau Coal Field (Figure 6-1). Each zone is the product of a high angle block fault with extensive minor fracturing within the graben. The Joes Valley Fault is the largest zone. As shown in Figure 6-1, the zone lies several miles west of the Co-Op permit area. The Pleasant Valley Fault Zone is vertical with between a few ft to 100 ft displacement (Doelling, 1972), although greater displacement occurs locally. The Bear Canyon #1, #2, #3, and #4 Mines operate within this fault zone. The North Gordon Fault Zone, which occurs near the eastern boundary of the Wasatch Plateau field, is the least extensive of the zones. The trends of the faults have a complex pattern. Displacement is generally less than 800 ft (see Plate 6-1 for a larger scale view of faults within the permit area).

TABLE 6-1 Generalized Section of Rock Formations, Wasatch Plateau Coal Field[1]

System	Series	Stratigraphic Unit		Thickness (feet)	Description
TERTIARY	Eocene	Green River Formation		–	Chiefly greenish lacustrine shale and siltstone.
		Wasatch Group	Colton Formation	300-1,500	Varicolored shale with sandstone and limestone lenses, thickest to the north.
	Paleocene		Flagstaff Limestone	200-1,500	Dark yellow-gray to cream limestone, evenly bedded with minor amounts of sandstone, shale and volcanic ash, ledge former.
			North Horn Formation (Lower Wasatch)	500-2,500	Variegated shales with subordinate sandstone, conglomerate and freshwater limestone, thickens to north, slope former.
CRETACEOUS	?				
	Maestrichthian	Mesaverde Group	Price River Formation	600-1,000	Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope former.
	Campanian		Castlegate Sandstone	150- 500	White to gray, coarse-grained often conglomeratic sandstone, cliff former, weathers to shades of brown.
			Blackhawk Formation *MAJOR COAL SEAMS*	700-1,000	Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick *coal* seams.
			Star Point Sandstone	90-1,000	Yellow-gray massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward.
	Santonian	Mancos Shale	Masuk Shale	300-1,300	Yellow to blue-gray sandy shale, slope former, thick in north and central plateau area, thins southward.
			Emery Sandstone *COAL (?)*	50- 800	Yellow-gray friable sandstone tongue or tongues, cliff former, may contain *coal* (?) in south part of plateau if mapping is correct, thickens to west and south. *Coal* may be present in subsurface to west.
	Coniacian		Blue Gate Member	1,500-2,400	Pale blue-gray, nodular and irregularly bedded marine mudstone and siltstone with several arenaceous beds, weathers into low rolling hills and badlands, thickens northerly.
	Turonian		Ferron Sandstone Member *MAJOR COAL SEAMS*	50- 950	Alternating yellow-gray sandstone, sandy shale and gray shale with important *coal* beds of Emery coal field, resistant cliff former, thickens to the south.
	Cenomanian		Tununk Shale Member	400- 650	Blue-gray to black sandy marine slope forming mudstone.
	Albian	Dakota Sandstone *MINOR COAL*		0- 60	Variable assemblages of yellow-gray sandstone, conglomerate shale and *coal*. Beds lenticular and discontinuous.

1(Doelling, 1972, pg. 68)

Figure 6-1 Principle Structural Features in the Wasatch Plateau



Reference: Doelling H.H 1972. Central Utah Coal Fields Sevier-Sanpete, Wasatch Plateau, Book Cliffs and Emery. Utah Geological and Mineralogical Survey, Salt Lake City.

Cordova
Earth fax Engineering
Stokes

Plate 5-3 shows the topography of the area. The permit area is generally rugged, with elevations varying from 7,000 to about 10,000 ft above sea level. Slopes in the vicinity of the permit area vary from more than 210 pct (65 deg) east of Star Point to less than 4 pct (2 deg) on Gentry Ridge.

Stratigraphy

All of the geologic formations exposed on or adjacent to the permit area are Cretaceous members of the Mesaverde group, with the exception of the North Horn Formation, which is Tertiary (Table 6-1 & Figure 6-1). The minable coal seams are located in the Upper Cretaceous Black hawk Formation.

Mancos Shale

The Mancos Shale, which underlies the Mesa Verde group (Table 6-1), consists of interbedded shale and sandstone members. The uppermost member of the Mancos Shale, directly underlying the Star Point Sandstone, is the Masuk Shale (Doelling, 1972). The Masuk is a dark gray marine shale with thin, discontinuous layers of gray limestone and sandstone (Stokes, 1964).

The Masuk is a soft unit in its exposures but usually forms part of the cliffs rising to the top of the Wasatch Plateau. To the West, it changes faces and joins with the Emery and Star Point sandstones (Doelling, 1972).

Star Point Sandstone

The Star Point Sandstone, the basal formation of the Mesaverde group (Doelling, 1972), is light-colored, fairly well sorted marine sandstone of medium to fine grain (Spieker, 1931). North of the Wattis Canyon area the Star Point Sandstone divides into three tongues.

To the South, the tongues are essentially fused into one massive cliff-forming unit. The Star Point becomes thicker to the southeast, ranging from 400 to 460 ft near the eastern edge of the lease area to 600 ft or more near the central part of Huntington Canyon (Spieker, 1931).

Descriptive core logging of the Star Point Sandstone was conducted in three in-mine drill holes installed in 1992 as part of a hydrogeologic evaluation (EarthFax Engineering, 1992). During the investigation, it was revealed that the Star Point Sandstone beneath the permit area is comprised of three separate sandstone units (in descending order: the Spring Canyon, Storrs, and Panther Tongues) interbedded with two mudstone units (inferred to be tongues of the Blue Gate member of the Mancos Shale). The core logs from the in-mine drill holes are shown in Appendix A.

Black hawk Formation

Overlying the Star Point Sandstone is the coal bearing Black hawk consisting of alternating sandstone, shale, and coal beds, with thin beds of argillaceous freshwater limestone occurring occasionally. The sequence represents deposition alternations between littoral and lagoonal sediments. The formation is approximately 1,000 ft thick, with the valuable coal seams located within the lower 400 ft (Doelling, 1972). The sandstone beds are fine to medium-grained

(Spieker, 1931). The sands of the Black hawk are generally cemented by calcium carbonate or silica, with the exception of a few localized areas in which the cement is almost entirely clay. Iron is also present in the cement of all but the pure white sandstone (Spieker, 1931).

An exception to above mentioned sandstone is the Aberdeen Sandstone, a coarse-grained, white sand that is traceable from the northern part of the Wasatch Plateau coal field southward to the northwest slopes of Gentry Mountain (Spieker, 1931). The generally discontinuous nature of the Black hawk and apparent low specific water yield (Cordova, 1964) indicates that the water yielding capabilities of the Black hawk is only of local importance.

Three general types of shale, all continental in origin, have been identified in the Black hawk formation (Spieker, 1931): ordinary clay shale, carbonaceous shale, and smoke-gray shale. The ordinary clay shell is gray or green, granular, and normally soft at the outcrop; the carbonaceous shell is brown to black, massive, and laminated; and the smoke-gray shell is tough and leathery, and in its unweathered state is hard and homogeneous (Spieker, 1931). Shale acts as an effective barrier to the vertical movement of water within the Black hawk Formation. Therefore, a significant portion of the water that reaches the Black hawk probably percolates downward until it reaches a shale layer, which causes horizontal movement to the surface or another "drain" (i.e. sandstone finger) within the formation.

Castlegate Sandstone

The Castlegate Sandstone, generally considered the basal member of the Price River Formation (Spieker, 1931) consists of massive, highly resistant medium to coarse-grained sandstone beds containing, in places, conglomerate with a matrix of grit (Doelling, 1972). It is thought to be of marine origin (Paul Wier Company, 1977). Although the Castlegate overlies the Black hawk Formation, it appears barren of coal in the plateau lease area.

Price River Formation

The lithologic characteristics of the Price River Formation and the underlying Castlegate Sandstone are similar; however, the castlegate member is differentiated from the Price River Formation in that it consists of medium to coarse-grained sandstone beds with occasional lenses of shale. Although the unit has a high porosity, its apparent low permeability (Cordova, 1964) reduces its water yielding capabilities except through fractures.

North Horn Formation

The youngest geologic formation within the permit area is the North Horn Formation, which caps Price River Formation on Gentry Mountain (Doelling, 1972). The North Horn, the lowest member of the Wasatch Group, consists of variegated shale's, irregular beds of gray, brown, or cream colored sandstone of various textures, and thin beds of steel-gray and cream colored limestone (Spieker, 1931).

Geology of Coal and Adjacent Units

Multiple coal seams are found in the lower 350 ft of the Black hawk Formation. In ascending order the seams are as follows: Hiawatha, Blind Canyon, Bear Canyon, upper beds, and the Tank Seam (Table 6-2).

Small rider seams also exist interbedded in the black hawk formation. The majority of these seams occur between the Bear Canyon and Tank Seam, which are often referred to as the "Upper beds."

None of the coal lies at depths of more than 1,800 ft. in the study area. Depth should not be a limiting factor in mining.

It was noted in the field that strata situated at elevations consistent with the upper beds structural horizon were badly burned and not of economic importance, with the exception of the Tank Seam, which has an average thickness of 7 feet in the permit area, but disappears to the North.

Table 6-2 Coal Beds, Lower Huntington Canyon

LAYER	FT
TANK SEAM	0-8
Interval	220-250
BLIND CANYON BEDS	0-14
Interval	40-110
HIAWATHA	5-8
Interval	5-8
STAR POINT SANDSTONE	

The Tank seam outcrops locally in the Southern portions of the study area. Drilling in the Bear Canyon Mine indicates minable thickness within the permit area. Drillhole logs are found in Appendix 6-A. The seam, a member of the upper beds of the Black hawk formation, achieves minable thickness only in the Southern portions of Bear Canyon and Fish Creek Canyon. Drillholes North of the study area have shown the Tank Seam to be nonexistent to the North.

The Blind Canyon and Bear Canyon seams were measured and observed at various points in the study area by the author. However, these seams were traceable only locally in Bear Canyon. Limited traceability of these two seams is attributed to the lenticular nature of the seams, the extent of slope debris acting as a cover and/or depositional irregularities. H. H. Doelling indicates the Bear Canyon seam is present in Left Fork of Fish Creek Canyon (east of Bear Creek Canyon) with a thickness of 6.5 ft. However, this measurement was not verified in the field, possibly because this particular exposure has since been covered by slope debris.

A small adit approximately 50 ft in length and interpreted as penetrating the Bear Canyon seam (measurement M-5), and a longer adit approximately 300 ft in length and interpreted as penetrating the Blind Canyon seam (measurement M-7), were discovered in Bear Creek Canyon,

Section 24, Township 16 South, Range 7 East. The full extent and history of these workings is not known. The fact that these two seams are not traceable for any significant area beyond these old workings indicates the subordinate nature of the Bear and Blind Canyon seams.

The Bear Canyon Mine is located in the SW 1/4 of Section 24, Township 16 South, Range 7 East. Two seams were worked there, the upper of which was the Bear Canyon seam (elevation 7,340 ft). This interpretation is based on the seams stratigraphic position above the Star Point Sandstone. The Blind Canyon seam apparently has pinched out or has been replaced in this locality. The mine lies on the west side of the Bear Canyon fault. The presence of the Hiawatha and Bear Canyon seams at the mine lend credence to the author's opinion that these seams are probably present across canyon to the east where they were not traceable nor measurable due to slope cover.

The Hiawatha seam was identified throughout the majority of the study area based on its stratigraphic relationship with the underlying Star Point Sandstone. The Star Point Sandstone is continuous and conspicuous within the area covered by this report. The Hiawatha seam was also measured in Left Fork of Fish Creek Canyon Doelling states that "extensive mining under Gentry Mountain (a short distance due north of Bear Canyon) reveals that the Hiawatha is continuous in the anticipated thickness". Where identified and measured, the Hiawatha seam achieved minable thickness in all but one instance (3.3 ft-measurement M-2). However, recent drilling has demonstrated that the Hiawatha seam is not continuous through this area. Mining and drilling in the Hiawatha seam has identified several large sandstone channels and scours which have rendered much of the Hiawatha seam unminable in the vicinity of Bear Creek and

Fish Creek Canyons. Specific work accomplished is shown on the Hiawatha seam Isopach map (Plate 6-15).

Structure

Structurally the strata in the Wasatch Plateau generally dip southerly (slightly southeast or southwest) at angles of 1 to 3 deg. Three major north-south trending fault zones have been defined in the Wasatch Coal Field. Each zone is the product of a high block fault with extensive minor fracturing within the graben. The Bear Canyon Mine is located in the Pleasant Valley Fault Zone. The vertical displacement varies between a few ft and 200 ft plus. A major fault separates the Bear Canyon Mine from the Trail Canyon Mine. (Note: Geotechnical sections are located in Appendix 2-A and the mine is mapped on Plates 5-1A, 5-1B, and 5-1C). Displacement on this particular fault is estimated to be 220 ft. During the mining of the Blind Canyon Seam several minor faults were discovered in the Trail Canyon Mine. These faults may affect the mining of other seams.

R645-301-621 General Requirements

All of the geological formation exposed on or adjacent to the permit area are Cretaceous members of the Mesa Verde group, with the exception of the North Horn Formation, which is Tertiary. The minable coal seams are located in the upper Cretaceous Black hawk Formation.

General Stratigraphy

The exposed geologic column, in ascending order, consists of the Mancos Shale, the Star Point Sandstone, coal-bearing Black hawk Formation and the Castlegate Sandstone Member of the Price River Formation. All of these Geologic units are Cretaceous in age. The Star Point Sandstone through the Price River Formation composes the Mesa Verde Group in this locality.

The Mancos Shale forms the initial steep slopes rising from the washes which in turn are overlain by the initial cliff-forming Star Point Sandstone described in R645-301-620.

The Black hawk Formation is composed of alternating sandstones, shales, mudstones and coal representing marine, transitional and terrestrial varieties of sedimentation. Depositional environments of the Black hawk Formation include littoral, lagoonal, estuarine and swamp type environments. The Black hawk outcrops to form a step and slope topography slightly less resistant than the Star Point below and the Castlegate above. Multiple coal seams are found within the lower 350 ft of the Black hawk.

The Castlegate Member of the Price River Formation makes up a massive, resistant cliff-forming unit above the Black hawk.

Structure

The Bear Canyon Fault, which is part of the north-south trending Pleasant Valley Fault Zone, marks the eastern boundary of the permit area. Displacement on this particular fault is estimated by C.W. Mining to be 200 ft+ in the vicinity of Bear Creek Campground on the north side of State Highway 31. The west side of the fault is down relative to the east side. Strata immediately bordering the fault are disturbed and inconsistent in spatial attitude with equivalent strata in the study area east of the Bear Canyon fault. This will no doubt have a limiting effect on the extent to which coal can be mined in the immediate vicinity of the fault. Strata east of the fault are nearly horizontal in attitude providing excellent mining conditions.

The Blind Canyon Fault, also part of the Pleasant Valley Fault Zone, marks the western boundary of the mine area. Displacement on this normal fault is estimated to be 220 feet, west side down.

Coal outcrops slightly lower in elevation in the southern portion of the area than in the northern portion.

Small faults noted in the field along outcrops were interpreted to be largely of non-tectonic origin (e.g. landslide and slump) by C. W. Mining. Other faults observed did not express displacement of sufficient magnitude to prohibit mining.

No geologic conditions exist within the permit area, which will obstruct or inhibit reclamation activities. The affects of the geologic structures on groundwater movement are discussed in Appendix 7-N, Section 2.4.3.

R645-301-622 Cross Sections Maps and Plans

622.100 Elevations and Locations of Core Samples

The elevations and locations of test borings and core samplings are given in Appendix 6-A. Additional drill hole logs can be founding in Appendix 7-A.

622.200 Nature Depth and Thickness of Seam to be Mined

This is shown on Plate 6-3 (Tank Seam), Plate 6-7 (Bear Canyon Seam), Plate 6-11 (Blind Canyon Seam), and Plate 6-15 (Hiawatha Seam).

622.300 Coal Crop Lines and Strike and Dip of Coal Seam

This is shown on Plate 6-4 (Tank Seam), Plate 6-8 (Bear Canyon Seam), Plate 6-12 (Blind Canyon Seam), and Plate 6-16 (Hiawatha Seam).

622.400 Location of Gas and Oil Wells

There are no gas or oil wells within the permit area.

R645-301-623 Geologic Information

623.100 Acid or Toxic Forming Strata

Copies of test results from coal samples taken within the permit area are included in Appendix 6-C. The coal quality is shown on page 6C-2. Analyses for acid- or toxic-forming materials in the coal, roof, and floor rock are shown on pages 6C-7 through 6C-21. Table 2-4a. lists the parameters to be tested for in roof, floor and mid-seam analyses. Coal and rock sample locations are shown on Plates 5-1. Engineering and material properties of the coal and surrounding rock are discussed on page 6C-22.

623.200 Geologic Information to Determine Reclamation

Geologic information to assist in determining whether reclamation can be accomplished is discussed in R645-301-724.

623.300 Geologic Information Pertaining to Subsidence

Geologic Information to assist in preparing the subsidence control plan is given under R645-301-332 (Anticipated Impacts of Subsidence), 645-301-525 (Subsidence Control Plan).

R645-301-624 Additional Geological Information

624.100 Geology in Permit and Adjacent Areas

This information is given in R645-301-620, R645-301-621, and R645-301-724.

624.110 Cross Sections and Maps and Plans

This is addressed under R645-301-622

624.130 Literature and References

Geologic Literature and references are given in R645-301-620.

624.200 Removal of Strata

Does not apply.

624.300 Test Boring

In 1992, C. W. Mining Company drilled 3 in-mine test holes through the Star Point Sandstone to the top of the Masuk Shale. These holes are shown on Plate 7-4 as DH-1A, DH-2, and DH-3, and were later completed as monitor wells. The test holes, shown in Appendix 6-A, revealed the Star Point Sandstone beneath the permit area to be comprised of three separate sandstone tongues interbedded with two mudstone units inferred to be tongues of the Bule Gate member of the Mancos Shale, referred to as Mancos No. 1 and Mancos No. 2. In 1993, DH-3 was abandoned due to pillaring activities, and was sealed in accordance with R645-301-631. It was replaced by DH-4, shown on Plate 7-4.

Spring Canyon Tongue. The Spring Canyon Tongue of the Star Point Sandstone, the uppermost unit, is 88 feet thick at DH-1, 103 feet thick at DH-2, and 98 feet thick at DH-3. It is generally light gray with minor dark minerals, but varies from dark gray to white. The grains range in size from fine to medium, and are moderately well sorted, subangular to subround, and well cemented with calcium carbonate. The unit is generally moderately- to well indurated. Bedding is variable through the unit, from massive to laminated, with muddy zones and partings and locally dense bioturbation. The contact with the overlying Hiawatha coal seam of the Black hawk Formation is abrupt; the lower contact with the Mancos No. 1 mudstone tongue is gradational.

Storrs Tongue. The Storrs tongue is 96 feet thick at DH-1A, 105 feet thick at DH-2, and 120 feet thick at DH-3. It is generally light gray to dark gray, with minor dark minerals. The grains range in size from very fine-to-fine, and are moderately well sorted, sub angular to sub round, and well cemented with calcium carbonate. The unit is generally well indurated. Bedding is variable through the unit, from massive to laminated, with muddy zones and partings and locally dense bioturbation, particularly in the lower portion of the unit. The contacts with the overlying Mancos No. 1 and underlying Mancos No. 2 mudstones are gradational. The Storrs Tongue Sandstone is generally finer grained, denser, more highly indurated, and less permeable than the other two Star Point Sandstone tongues.

Panther Tongue. The Panther Tongue is 105 feet thick at DH-1A, 88 feet thick at DH-2, and 97 feet thick at DH-3. It is generally light gray with minor dark minerals, but, like the Spring

Canyon and Storrs tongues, varies from dark gray to white. The grains range in size from fine to coarse, and are poorly to moderately well sorted, round to sub round, and poorly cemented with calcium carbonate. The unit is generally poorly to moderately-well indurated, and locally friable. Bedding is variable through the unit, from massive to laminated, with muddy partings and local bioturbation. The contact with the overlying Mancos No. 2 mudstone is gradational; the lower contact with the Mancos Shale is abrupt. The Panther Tongue sandstone is less dense, coarser-grained, less well cemented, less indurated, and more permeable than the Spring Canyon and Storrs tongues.

Additional drill hole information is given in Appendix 6-A and Appendix 7-A. A chemical analysis of the coal seam is found in Appendix 6-C.

624.340 Properties of Clay

No significant amount of clay was detected in the samples analyzed. (See Appendix 6-C)

R645-301-630 Operation Plan

R645-301-631 Casing and Sealing of Exploration Holes

Drillholes DH-1A, DH-2, and DH-3, were completed as monitor wells in 1992. The completion of these wells are shown and described in Appendix 7-N. DH-3 was abandoned in 1993 due to pillaring in the location of DH-3. It was replaced by DH-4, shown on Plate 3-4A. DH-4 was drilled into the Spring Canyon Member of the Starpoint Sandstone in January of 1994 and was also completed as a monitor well. The drillhole logs and well completion diagrams for these four wells are included in Appendix 7N-G. All exploratory boreholes drilled by C.W. Mining will be sealed as described in R645-301-529. Holes will be closed and sealed in compliance with all applicable state and federal regulations.

R645-301-632 Subsidence Monitoring

A Subsidence Monitoring Plan along with a map showing the location of monitoring points (Plate 5-3) is given in Chapter 5 under R645-301-525.

Reference:

Cordova 1964. Hydrogeologic reconnaissance of part of the headwaters area of the Cordova, Utah Geological and Mineralogical Survey, Salt Lake City.

Doelling H.H 1972. Central Utah Coal Fields Sevier-Sanpete, Wasatch Plateau, Book Cliffs and Emery. Utah Geological and Mineralogical Survey, Salt Lake City.

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Earth fax Engineering 1993. Revised Hydrogeologic Evaluation of the Bear Canyon Mine Permit and Proposed Expansion Areas.(See Appendix 7-N.)

Stokes, William Lee, 1964. Geologic map of Southeastern Utah, Washington D.C., Williams and Heintz Map Corp.

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